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Kennecott

July 31, 1987

Mr. Ben Haynes
U.S. Environmental Protection Agency
Office of Solid Waste - WH-565E
401 M Street, S.W.
Washington, D.C. 20460

Re: Kennecott Copper Processing Data

Dear Mr. Haynes:

Enclosed is a report presenting the results of Kennecott's review of EPA's data on various materials generated at our Utah copper processing facilities. This report is offered in response to EPA's letter of May 22 to Mr. Rod Dwyer of the American Mining Congress seeking review of data to be used in preparing the upcoming Report to Congress on "fast track" mineral processing wastes. Kennecott appreciates the opportunity to review EPA's data prior to preparation of the Report to Congress.

Kennecott is aware that the results of our data review are being submitted after the deadline established by EPA for inclusion in the Report to Congress, and we apologize for any inconvenience this may cause. Nevertheless, we urge EPA to incorporate our results into the Report to Congress. As noted in our letter of June 15, we only received EPA's request on June 5, and it was not possible for us to review EPA's data and prepare a response prior to the June 12 deadline established by EPA. Our review was further complicated by internal Kennecott developments during June and July, including relocation of our offices and reopening of our smelter and refinery, which had been closed since early 1985. We also would point out that the Mining Waste Management Plan recently issued by EPA includes a schedule for producing the Report to Congress that provides for "compilation of existing data" through the end of July, with a draft Report scheduled for the end of August and a final report not due until next January (Table 2-2, p. 2-15). This schedule would appear to permit inclusion of our results in EPA"s Report to Congress, and we hope that the agency will do so in the interest of preparing a Report that is as accurate as possible.

In addition to submitting the results of our data review, Kennecott would like to comment briefly on two points raised in EPA's letter of May 22. First, we support EPA"s position that "if the comments received indicate that the material is managed in such a way that it is not a solid waste at any of the facilities where it is generated, then we do not plan to include the material in the Report" (p. 2). As detailed in our enclosed report, most of the materials generated at our smelting and refining facilities are processed to recover copper or precious metals, and many of them are richer than our copper ore itself. The reprocessing techniques utilized by Kennecott are common in the copper, smelting and refining industry and, in fact, have been used in the U.S., Zaire, Zambia, and other countries for over 30 years as a means to maximize recoveries of metals from mineral resources. Second, Kennecott opposes EPA's statement that "the mining waste exclusion does not necessarily apply to all of the materials listed" on EPA's data sheets (id.). In our view, the exclusion applies to all of the materials listed by EPA because they are all indigenous to copper processing operations. The mining waste exclusion was intended to cover all such materials, including those generated by pollution controls without which our facilities could not be operated. Support for our position is provided in our comments to EPA on the Mining Waste Exclusion (filed January 2, 1986), and we intend shortly to provide additional detailed support in comments on EPA's Mining Waste Management Plan.

Sincerely,

Gregory H Boyce

Gregory H. Boyce

Enclosure

c: Robert Walline, w/enc.
Rod Dwyer, w/enc.

Introduction

This report is submitted to the U. S. Environmental Protection Agency (EPA) in response to EPA's request to the American Mining Congress (AMC) for comments and review of data relative to process and waste streams at Kennecott's Utah smelter/refinery complex and other metals processing facilities.

Specifically, EPA has provided estimates of the "generation"[1] rate, water content, and management practices relative to several materials, characterized as wastes, produced at Kennecott's Utah smelter and refinery and at other domestic copper production facilities. The sources of these estimates include ICF (an EPA contractor) calculations, earlier EPA and contractor studies,[2] industry surveys, and U.S. Bureau of Mines (USBM) data. Because various surrogates were employed in lieu of direct measurement or field work, EPA is providing an opportunity for Kennecott and others to review these estimates and submit comments and site-specific revisions. These responses will be considered by EPA in the preparation of the "Second Report to Congress on Ore and Mineral Processing Wastes."

Kennecott appreciates the opportunity to provide substantive comments to EPA on this important matter.

"Wastes" Included in EPA Estimates

At the outset, it is important to address EPA's characterization of many of these materials as "wastes." EPA provided data for some 15 materials, produced at Kennecott's Utah facility. These 15 materials are identified in Table 1, and include the

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[1]The word generation is placed in quotes because EPA appears to use this in connection with wastes, e.g., as waste generation rate. Because Kennecott does not agree with this characterization for most of the materials discussed here, the term "production rate" is used instead.

[2]See, e.g., "Overview of Solid Waste Generation, Management, and Chemical Characteristics, Primary Copper Smelting and Refining Industry," PEI Associates, Inc., Cincinnati, Ohio, December 1984, and associated references.

TABLE I.
SMELTER AND REFINERY WASTES IDENTIFIED BY EPA

Process Waste Water

Furnace Brick

Scrap Metal, Sweepings, Screenings, etc.

ESP, Baghouse, and Other Dusts

Chamber Solids and/or Scrubber Sludge

Slag from Smelting

Acid Plant Blowdown

Bleed Electrolyte

Waste Water Treatment Plant Sludge

Spent Catalyst From Acid Plant

Contact Cooling Water

Slag from Anode Furnace

Slag From Converting

Slimes

Cathode Preparation Wastes

following: process waste water, furnace brick, scrap metal sweepings, screenings, etc., ESP baghouse and other dusts, chamber solids and/or scrubber sludge, slag from smelting, acid plant blowdown, bleed electrolyte, waste water treatment plant (WWTP) sludge, spent catalyst from acid plants, slag from anode furnaces, contact cooling water, slag from converters, refining slimes, and cathode preparation wastes.

To be sure, some of these materials, such as WWTP sludge, are discarded at present and might properly be characterized as "wastes." But, as discussed below, the majority of materials identified by EPA are processed by Kennecott and many other copper producers to recover valuable products. EPA's use of the term "waste" is inappropriate for these materials.

Specific comments on various smelter and refinery materials are provided below. But, to lend perspective, it is useful to provide some brief background on the process of mining and processing (smelting and refining) of copper.

— Basis for a Quantitative Perspective

To begin, copper ore mined in the United States and, after concentration (if required), shipped directly to smelters in recent years has averaged less than 0.6% copper. In 1984, for example, the recoverable copper content of copper ores was only 0.52%,[3] equivalent to a yield of approximately 10.5 pounds of copper per ton of ore. Highly efficient materials handling, separation, and processing technologies employed by the domestic copper industry enable such "lean" or low grade ore to be mined profitably. Although a material-specific analysis must be completed to determine the economics of recovery for other copper-bearing materials, the copper content of the ore itself is a useful benchmark to keep in mind when considering what material is or is not a waste.

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[3] Jolly, J. L., and D. L. Edelstein, "Copper," chapter in Minerals Yearbook 1984, U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1985, p. 320. The ore grade mined in many other countries (e.g., Chile) is higher than that mined in the United States.

Reactor (smelting) slag, for example, is a material that is separated from the copper rich (71%) matte produced in the Noranda process used at Kennecott's Utah smelter. This slag averages approximately 7% copper[4] -- 13.5 times as rich as the copper ore itself. Other factors held constant, it is much more attractive to recover copper from a material that contains 7% copper than to mine and concentrate 0.52% ore. The copper ore benchmark makes it easy to understand why these slags are highly valuable and are returned to the reactor at the Kennecott facility.

As a second example, treatment and recovery of by- or co-products of copper smelting and refining is often critical to the economics of copper production. Studies by USBM[5] indicate that by-product credits have averaged 14 cents per pound of copper produced -- effecting a 16% reduction in the cost of domestic copper production over the years from 1981 to 1984. It is no exaggeration to claim that most domestic copper mines would not be economically viable were it not for by-product recovery credits. Refinery "slimes" (an unfortunate term-of-art in this context), in particular, included in the "wastes" identified in the EPA report, are highly valuable feed materials for a precious metals refinery co-located with the Utah copper refinery. (National data for by- and co-products produced from copper ores for 1978 and 1982 are shown in Tables 2A and 2B.[6] As can be seen, an appreciable fraction of the domestic supply of several important

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[4]Not all reactor slags are as rich in copper and slags from some smelters are discarded or solid (see later discussion in text). This serves as an interesting illustration of the uniqueness of the mineral processing industries and the need for case-by-case analysis in a RCRA context. Although a common name, "slag," is employed, at some smelters slag is "copper-rich" and clearly a process material, and at other smelters is discarded. Similar remarks can be made for many of the materials identified in the EPA report.

[5]Jolly, J. L. W., "Copper," chapter in <u>Mineral Facts and Problems</u>, 1985 Edition, U. S. Department of the Interior, Bureau of Mines, Bulletin 675, 1986, Washington, D. C., p. 212.

[6]Jolly, J. L. W., "Copper," chapter in <u>Mineral Facts and Problems</u>, 1985 Edition, U.S. Department of the Interior, Bureau of Mines, Bulletin 675, 1986, Washington, D.C., p. 210. H. J. Schroeder and J. H. Jolly, "Copper," chapter in <u>Mineral Facts and Problems</u>, 1980 Edition, U.S. Department of the Interior, Bureau of Mines, Bulletin 675, 1986, Washington, D.C., p. 236.

TABLE 2A.
U.S. COPPER BY-PRODUCT AND CO-PRODUCT RELATIONSHIPS IN 1978

Product	Unit	Quantity	Percent of Total Output
Arsenic	Metric tons	W	W
Rhenium	Metric tons	W	100.0
Selenium	Metric tons	231	100.0
Palladium	1,000 troy ounces	7	100.0
Tellurium	Metric tons	W	100.0
Silver	1,000 troy ounces	12,501	31.7
Platinum	1,000 troy ounces	I	100.0
Molybdenum	Metric tons	18,992	31.8
Gold	1,000 troy ounces	367	36.7
Nickel	Metric tons	W	W
Sulfur	Metric tons	819,757	7.3
Zinc	Metric tons	4,042	1.3
Iron	Metric tons	W	W
Lead	Metric tons	325	I
Uranium	Metric tons	W	W
Copper	Metric tons	1,340,432	98.8

W = Withheld by USBM to avoid disclosing company proprietary data; I = Less than 1/2 unit.

Source: U. S. Bureau of Mines

TABLE 2B.
DOMESTIC COPPER BY-PRODUCT AND CO-PRODUCT RELATIONSHIPS IN 1982

Co-product and/or By-product	Unit	Quantity	Percent of Total Output
Arsenic	Metric tons	W	100.0
Rhenium	Metric tons	W	100.0
Selenium	Metric tons	243	100.0
Palladium	1,000 troy ounces	7	100.0
Tellurium	Metric tons	W	100.0
Silver	1,000 troy ounces	9,566	23.8
Platinum	1,000 troy ounces	I	100.0
Molybdenum	Metric tons	12,527	35.5
Gold	1,000 troy ounces	235	16.0
Nickel	Metric tons	W	W
Sulfur	Metric tons	614,754	6.3
Zinc	Metric tons	W	W
Iron	Metric tons	W	W
Lead	Metric tons	191	I
Copper	Metric tons	1,114,901	97.2

W = Withheld by USBM to avoid disclosing company proprietary data.
I = Less than 0.1%.

Source: U.S. Bureau of Mines

materials -- including arsenic, rhenium, selenium, palladium, tellurium, silver, platinum, molybdenum, and gold -- is obtained from copper ores. In recent years, for example, more than one-third of domestic gold and silver output has been produced as a by- or co-product from copper ores.)

A typical analysis of refining slimes produced at Kennecott's Utah facility is as follows: copper, 25%; gold, 150 ounces per ton; silver, 2200 ounces per ton; and recoverable quantities of selenium and tellurium.[7] Such a material is very much "richer" than gold or silver ores now being mined (to say nothing of copper). For example, according to USBM,[8] "the average recovery grade of gold ores processed from lode mine sources was 0.06 ounce per short ton, while placer gravels yielded an average of 0.007 ounce per cubic yard washed." (Emphasis added) The gold content of Kennecott's refinery slimes (150 ounces per ton) is 2,500 times greater than that of gold ores processed from lode mine sources.

Likewise, Kennecott refinery slimes have a much greater silver content than domestic silver ores being mined. In 1983, for example, approximately 30 million troy ounces of silver were recovered from 7.5 million short tons of silver ore,[9] a ratio of only 4 ounces per ton. Refinery slimes (assaying 2,200 ounces of silver per ton) contain 550 times as much silver as domestic silver ores.

Certainly, Kennecott's refinery slimes cannot be termed a waste in any meaningful sense. Rather, this material should properly be classified as an "intermediate product."

These two examples, reactor slag and refinery slimes, serve as interesting illustrations of some of the material streams in the primary copper mining and processing in-

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[7] Kennecott, "Utah Copper Division Refinery," report and accompanying flow sheets, undated.

[8] Lucas, J. M., "Gold," chapter in Minerals Yearbook 1984, U. S. Department of the Interior, Bureau of Mines, Washington, D.C., 1985, p. 407.

[9] Reese, R. G., "Silver," chapter in Minerals Yearbook 1984, U. S. Department of the Interior, Bureau of Mines, Washington, D.C., 1985, p. 819.

dustry. Reactor slag is reprocessed by milling, concentration, and smelting. Refinery slimes, intermediate products, are sent to a precious metals refinery for recovery of valuable by- or co-products of copper.

An Intricate Flow Chart

Although elementary discussions of the primary copper production process present (or emphasize) what might be termed a "linear" or "series" relationship among the stages of production -- from mill to concentrator to roaster (if present) to smelting furnace (or reactor) to converter to anode furnace to casting wheel to electrolytic refinery -- the flow chart corresponding to actual copper processing operations is typically far more complex. The economics of extraction of low-grade copper deposits dictate that process and yield losses must be minimal. (As an interesting aside, baghouses and electrostatic precipitators were first installed by smelters to increase copper recovery by capturing flue dusts long before the Clean Air Act (CAA) was passed into law.[10]) Over time, processing technology has evolved to maximize copper recovery from low-grade porphyry ores. In consequence, numerous direct and indirect processing "loops" are an integral part of the flow chart of the modern copper-processing complex.

— Refinery Flows: An Example

Figure 1, for example, shows a functional block diagram of Kennecott's Utah copper refinery. Copper anodes produced in the smelter's anode furnaces and casting wheels are the principal feed, and copper cathodes and refinery slimes are the principal products. But additionally, over 20 other metal-bearing materials were produced at this refinery complex and returned to the smelter over the period 1982-1984. Figure 1 identifies 17 of these return flow streams and the point of entry (reactor or converter) at the smelter. These materials have a high copper or precious metals content. For example, on an

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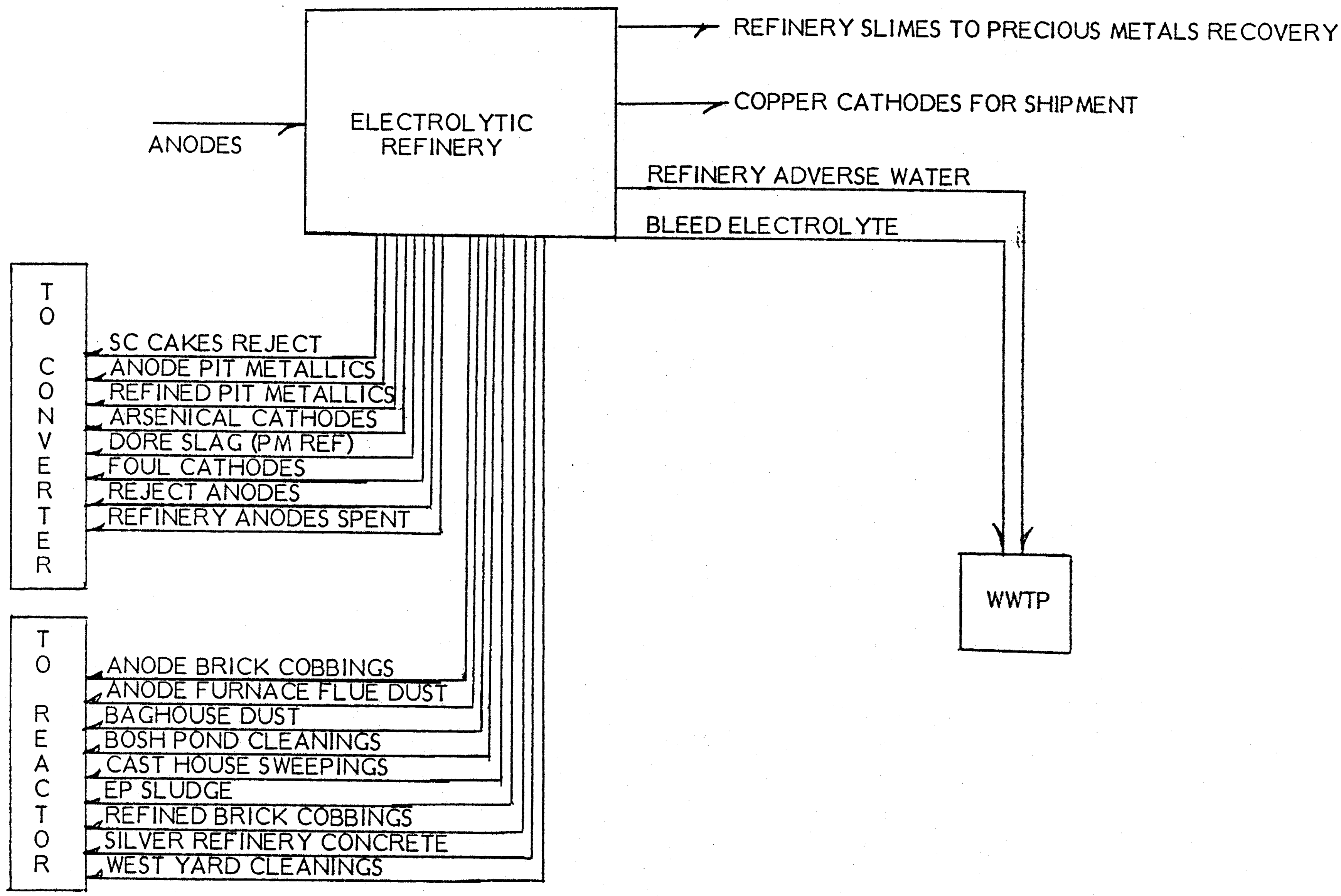
[10] Parsons, A. B., The Porphyry Coppers, AIME, New York, 1933, pp. 504, *et seq*.

FIGURE I.
AN ILLUSTRATION OF RECYCLE STREAMS IN THE PRIMARY COPPER PRODUCTION PROCESS: REFINERY OUTPUTS — 1982-1985



overall weight basis, these materials averaged 75% copper over the period 1982-1984. Even "anode brick cobbings," the brick residues from Kennecott's refinery anode furnaces, averaged approximately 26% copper over the period 1982-1984. Other materials, such as Dore slag, that are low in copper, contain precious metals in economically recoverable quantities.

Table 3 presents salient characteristics of these materials produced at Kennecott's refinery as taken from production records over the period 1982-1984.[11] The table shows (ranked in descending order of copper content) these material flows, the average copper content (%). All of these materials, particularly those which are low in copper, contain recoverable quantities of gold and silver. For convenience, Table 3 also presents the matching "waste" streams as defined by EPA. (No match could be found in EPA's taxonomy for reject anodes or Dore slag.)

Kennecott categorically rejects the blanket term "waste" to describe any of these materials shown in Table 3. All of these materials contain economically recoverable quantities of copper, gold, and silver, and Kennecott routinely reprocesses them through the smelter.

— Unfortunate Terms-of-Art (An Historical But Relevant Aside)

Table 4 shows popular dictionary definitions for several terms-of-art used in the metals processing industry. In common, as opposed to technical usage, these words generally have negative connotations (e.g., "tossed on the slag heap of society"). And, indeed, there is some historical basis for regarding these terms as descriptors of waste materials. For example, older copper smelter designs, such as the reverberatory furnace, produced slags that contained relatively little copper. A 1969 study indicated that the average copper content of reverberatory furnace slags in a sample of 13 operations was

[11] 1985 was an atypical year for the facility and the refinery was closed throughout 1986 and 1987 until June.

TABLE 3. METAL ASSAYS OF REFINERY REPROCESS STREAMS RANKED IN DESCENDING ORDER OF COPPER CONTENT.

	MATERIAL DESCRIPTION USED IN THIS REPORT	MATCHING EPA CATEGORY	AVERAGE PRODUCTION RATE TONS/YR.	AVERAGE ASSAY 1982-1984 COPPER %	GOLD OZ/TON	SILVER OZ/TON
C	ANODE PIT METALLICS	SCRAP METAL, SWEEPINGS, SCREENINGS	802.0	99.9%	1.11	15.43
C	FOUL CATHODES	CATHODE PREPARATION WASTES	1,296.4	99.9%	0.06	1.06
C	SC CAKES REJECT	SCRAP METAL, SWEEPINGS, SCREENINGS	3,830.5	99.9%	0.18	2.94
C	REJECT ANODES	NO MATCH	1,145.9	99.6%	0.89	14.00
C	ARSENICAL CATHODES	CATHODE PREPARATION WASTES	738.4	99.0%	0.07	1.26
C	REFINED PIT METALLICS	SCRAP METAL, SWEEPINGS, SCREENINGS	159.0	98.8%	0.82	12.02
N	ANODE FURNACE FLUE DUST	ESP, BAGHOUSE AND OTHER DUSTS	139.5	84.8%	0.40	37.56
	OTHER	SCRAP METAL, SWEEPINGS, SCREENINGS	54.3	69.7%	6.39	83.76
N	E. P. SLUDGE	CATHODE PREPARATION WASTES	1,175.1	47.4%	2.92	95.67
N	BOSH POND CLEANINGS	SCRAP METAL, SWEEPINGS, SCREENINGS	32.7	42.3%	0.08	4.47
N	CAST HOUSE SWEEPINGS	SCRAP METAL, SWEEPINGS, SCREENINGS	82.3	39.6%	0.69	17.92
N	REFINED BRICK COBBINGS	FURNACE BRICK	22.9	29.8%	0.30	3.36
N	ANODE BRICK COBBINGS	FURNACE BRICK	130.0	26.1%	0.42	10.14
N	SILVER REFINERY CONCRETE	FURNACE BRICK	74.4	3.9%	6.19	108.56
C	DORE SLAG	NO MATCH	721.2	2.9%	14.66	705.80
N	BAGHOUSE DUST	ESP, BAGHOUSE AND OTHER DUSTS	41.6	2.2%	4.20	314.32
	WEST YARD CLEANINGS	SCRAP METAL, SWEEPINGS, SCREENINGS	1,169.7	0.5%	0.22	5.87
		TOTAL OR AVERAGE	11,616.0	75.6%	1.57	60.79

TABLE 4.
DICTIONARY DEFINITIONS OF SEVERAL TERMS OF ART: BASIS FOR A MISUNDERSTANDING?

Word	Definition*
Dross	1. A scum formed on the surface of molten metal. 2. Waste matter; worthless stuff; refuse; rubbish.
Foul	1. Rotten, putrid, lazy. 2. So offensive to the senses as to cause disgust; stinking; loathsome: as, a foul odor. 3. Extremely dirty; disgustingly filthy.
Impure	1. Unclean, dirty 2. Mixed with foreign matter; adulterated
Scum	1. A thin layer of impurities which forms on the top of liquids or bodies of water, often as the result of boiling or fermentation. 2. The dross or refuse on top of molten metals. 3. Refuse; worthless parts of anything.
Slag	1. What is struck away (in metalworking). 2. The fused refuse or dross separated from a metal in the process of smelting.
Slime	1. Any soft, moist, slippery, sometimes sticky matter, as thin mud, the muccous coating on fish, etc. 2. Any moist or sticky substance that is considered filthy or disgusting.
Sludge	1. Mud, mire, or ooze covering the ground or forming a deposit at the bottom of bodies of water. 2. Finely broken drift ice. 3. Any heavy, slimy deposit, sediment, or mass, as the waste resulting from oil refining, the mud brought up by mining drill, the precipitate in a sewage tank, the sediment in a steam boiler, etc.
Smelt	1. To melt or fuse (ore, etc) so as to separate impurities from pure metal. 2. To refine to extract (metal) in this way.

*Webster's New World Dictionary of the American Language, The World Publishing Company, Cleveland & New York, 1951.

less than 0.5%.[12] These reverberatory furnace slags were discarded or sold for other purposes such as road bed or paving materials. The reason why the copper content of these reverberatory furnace slags was so low is because the copper content of the furnace slag is an increasing function of the copper content of the matte,[13] and the matte grades employed in reverberatory smelting were generally 40% or less.[14] But the newer smelting processes (generally adopted in the United States because of the Clean Air Act requirement to capture greater amounts of sulfur), such as the Mitsubishi, Outokumpu, and the Noranda reactor (used at Kennecott's Utah smelter) produce a much higher matte grade. The matte grade in Kennecott's smelter is approximately 70% copper. For this and other reasons, the copper content in the Noranda reactor slag is significantly higher -- the 7% figure cited earlier. Thus, although it may have been cost effective to discard smelter slags at one time (and Kennecott did so when it operated the conventional reverberatory smelter that was replaced by the Noranda reactor in 1977), slags from newer smelters are generally much too valuable to discard.[15] Nonetheless,

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[12]Biswas, A. K., and W. G. Davenport, Extractive Metallurgy of Copper, Pergamon Press, Oxford, 1980, p. 118.

[13]Biswas, A. K., and W. G. Davenport, Extractive Metallurgy of Copper, Pergamon Press, Oxford, 1980, p. 205. See also, H. K. Jalkansen, et al., "Some Novel Aspects of Matte Slag Equilibrium," in H. Y. Sohn, et al., Eds., Advances in Sulfide Smelting, AIME, Warrendale, Pa., 1983, pp. 277, et seq.

[14]Parsons (Parsons, A. B., The Porphyry Coppers, AIME, New York, 1933, pp. 483 et seq.) provides an interesting historical sidelight on the selection of the optimal matte grade for reverberatory smelters:

> "Control of the metallurgy of the smelting process really hinges on the converting operation. The heat required for converting matte is supplied by the burning or oxidation of the sulphur and iron in it. If the matte is too rich in copper it is deficient in iron and sulphur to serve as fuel. Also, a high-grade matte, other things being equal, can be produced only at the expense of making a dirtier slag (that is, one containing more copper) in the reverberatory. If the matte is too low in grade, it supplies adequate heat for converting, but as each ton contains less copper more matte must be converted, more iron fluxed off, and more slag must be returned to the reverberatory for re-treatment, with attendant increased cost. A compromise must be reached as to the best grade of matte under prevailing conditions, principally the cost of the various steps in the smelting process. About 40 per cent copper is the average, but the range is from 25 to 55 per cent." (Emphasis added.)

the original term-of-art, "slag," is still used to describe these higher copper-content materials. Copper "lexicography," to coin a phrase, has simply not kept pace with technological progress.

Consider another word -- impurity. This too has unpleasant or negative connotations in everyday speech. But, in the case of porphyry copper ores, many of the "impurities" are more valuable than the copper itself, as shown below. (Sources: Metals Week, 13 July 1987, "USBM 1987 Mineral Commodities Summaries"):

Material	Recent Price	Units
Copper	0.74	$ per pound
Gold	446	$ per troy ounce
Palladium	140	$ per troy ounce
Platinum	553	$ per troy ounce
Silver	7.48	$ per troy ounce
Molybdenum (as oxide)	3.25	$ per pound
Rhenium	350.0	$ per pound
Tellurium	10.0	$ per pound
Selenium	5.60	$ per pound
Nickel	3.20	$ per pound

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[15] Slag from the Noranda process, as employed at the Noranda Horne smelter in Canada, are processed in the same manner as the Kennecott Utah smelter (see P. J. Mackey, et al., "The Noranda Process - An Update," in D. B. George and J. C. Taylor, Eds., Copper Smelting - An Update, AIME, Warrendale, Pa., 1981, pp. 213, et seq.). Other "new" smelters use alternative recovery processes, such as a slag cleaning furnace (see e.g., T. J. Kim, "Flash Smelting of Copper in Korea," or T. Suzuki, et al., "Recent Operation of Mitshubishi Continuous Copper Smelting and Converting Process at Naoshima," in D. B. George and J. C. Taylor, Eds., Copper Smelting - An Update, AIME, Warrendale, Pa., 1981. For useful discussions of copper recovery from slags in direct copper smelting, see R. J. McClincy, et al., "Commercial Implications of Direct Copper Smelting," in H. Y. Sohn, et al, Eds., Advances in Sulfide Smelting, AIME, Warrendale, Pa., 1983, pp. 499, et seq.; P. R., Ammann, "The Kennecott Slag Cleaning Process" and J. C. Agarwal, "Process Analysis for Recovery of Metal Values from Copper Smelter Slags," in J. C. Yannopoulos and J. C. Agarwal, Extractive Metallurgy of Copper, AIME, New York, 1976. Finally, it should be noted that not all high matte grade processes produce slags with attractive recovery potential. The Inco process, for example, is reported to produce furnace slags with copper content low enough to be discarded (see J. G. Eacott, "The Role of Oxygen Potential and Use of Tonnage Oxygen in Copper Smelting," in H. Y. Sohn, et al., Eds., Advances in Sulfide Smelting AIME, Warrendale, Pa., 1983, p. 618.) Many older smelters still discard slag (see, e.g., "Overview of Solid Waste Generation, Management, and Chemical Characteristics, Primary Copper Smelting and Refining Industry," PEI Associates, Inc., Cincinnati, Ohio, December 1984, and associated references. Nonetheless, the same term, "smelter slag," is used to sescribe the high copper content Noranda or Mitshubish slags as reverberatory furnace slags.

At various times, those in the copper industry have also misused the word "waste," as, for example, when Parsons[16] in a classic 1933 text referred to converter secondaries as "slag, principally, and other copper-bearing waste material." (Emphasis added.) However, even at this early date, Parsons was aware that recovery economics demanded a more appropriate nomenclature, "intermediate products." Indeed, later in this same treatise[17] Parsons wrote:

> "But in the process of manufacturing blister out of concentrates a great many intermediate products are made, not through desire but through necessity. These include: Flue dust from roasters, reverberatories, and converters; slag from the converters; "skulls" from ladles; copper-impregnated brick from furnace linings; spillage and crusts of matte and copper from reverberatories and converters, from ladles and transfer cars or pots. All of these must find their way back to the circuit for re-treatment. Incidentally not all of them are indicated (the flow chart) as they would merely complicate the drawing." (Emphasis added.)

This was written long before the Resource Conservation and Recovery Act (RCRA) became law. So, although it is perhaps understandable that EPA has chosen to group these materials produced at copper smelters and refineries under the broad rubric "waste," in fact no such categorization is warrented.

Production Rates

Turning now to quantitative matters, Table 5 presents Kennecott's suggested revisions to EPA's data submittal. This table presents salient characteristics of various material flows through the Kennecott Utah smelter/refinery complex from 1982 to 1984.

Finally, Table 6 presents a convenient summary of production rates as given by EPA and as estimated here. Kennecott was unable to find exact matches for the following EPA waste streams; process waste water, and contact coolant. Presumably these streams are included in the "smelter adverse" and "refinery adverse" categories, but

[16] Parsons, A. B., The Porphyry Coppers, AIME, New York, 1933, p. 497.

[17] Parsons, A. B., The Porphyry Coppers, AIME, New York, 1933, p. 508.

TABLE 5
SMELTER AND REFINERY MATERIALS IDENTIFIED AS WASTES IN EPA REPORT

Basis: 200,000 tons per year capacity

MATERIAL TYPE	SLAG FROM SMELTING	ESP, BAGHOUSE AND OTHER DUSTS	SLAG FROM CONVERTING	REFINERY SLIMES	CATHODE PREPARATION PLANT WASTES
Description	Slag from Noranda Reactor (contains about 7% copper)	Anode furnace flue dust, refinery baghouse dust, and smelter flue dusts	Slag from converters (contains about 12% copper)	Refinery slimes	Arsenical cathodes, foul cathodes, E.P. sludge
Source(s)	Noranda Reactor	Anode furnace (copper refinery); baghouse, (silver refinery); flue dust (smelter)	Converter	Refining	Electrolyte purification (refinery)
Fate	Slags are sent to mill for grinding, and concentration. Concentrates (ca 40% copper) are sent to reactor. Tailings are sent tailings pond.	Refining materials are charged into reactor. Smelter flue dusts have been partially processed and/or stockpiled in past.	Slags are charged into Noranda reactor after cooling and crushing.	All material sent to precious metals refinery, because slimes contain copper and precious metals (gold and silver).	Arsenical and foul cathodes to converter, E.P. sludge to reactor.
Production Rate: tons/ ton anode	2.61	0.03655	0.14	0.0055	0.01697
Fraction Returned to Process	100% to mill; 17% of slag returned as concentrates to reactor.	100% of copper refinery anode furnace and silver refinery baghouse dusts to reactor. Smelter ESP dusts stockpiled at present (overall percentage processed = 40.23%	100%	100%	100%
Net Production Rate: tons/ ton anode	2.16 (as tailings)	0.02184	0	0	0
Net Production Rate: @ Capacity (tons) per year	432,516 (as tailings)	4,369	0	0	0
% Water	0%	0%	0%	Not available	Cathodes (0%)
Process Dynamics	Semi-batch, virtually prompt.	Batch	Semi-batch, virtually prompt.	Batch	Semi-batch
Remarks	1982-1984 Yearly smelter data.	1982-1984 Various sources. Plans call for 100% of this material to be processed in the future.	*Journal of, Metals*, March 1982.	UCD refinery, flowsheet, and accompanying text.	1982 - 1984 Smelter data report, refinery residuals.

TABLE 5.
SMELTER AND REFINERY MATERIALS IDENTIFIED AS WASTES IN EPA REPORT
(continued)

Basis: 200,000 tons per year capacity

MATERIAL TYPE	BLEED ELECTROLYTE	WWTP SLUDGE	PRECIOUS METAL REFINERY RESIDUALS	ACID PLANT BLOWDOWN	OTHER SMELTER PLANT WATERS
Description	Spent electrolyte	Sludge from high-lime precipitation process.	Dore slag.	Acid plant blowdown water[b]	Smelter adverse water (excludes acid plant blowdown)
Source(s)	Copper refinery tank house, silver refinery.	WWTP	Precious metals refinery	Acid plant	Smelter
Fate	Sent to WWTP.	Placed on surface impoundment.	Converter	Sent to WWTP.	Sent to WWTP.
Production Rate: tons/ ton anode	0.1796	0.3868	0.00381	17.5	10.5
Fraction Returned to Process	0%	0%	100%	0%	0%
Net Production Rate: tons/ ton anode	0.1796	0.3868	0	17.5	10.5
Net Production Rate: @ Capacity (tons) per year	35,920	77,360	0	3,500,623	2,100,374
% Water	85%[a]	38%	0	99%	99%
Process Dynamics	Not Available	Not Available	Virtually prompt.	Not Available	Not Available
Remarks	1983-1985	1983-1985	1982-984 Smelter Data Report		

[a]Personal communication, Utah Copper Refinery.
[b]Includes fresh water to the gas cooling towers which overflows to the humidifying towers and add to the blowdown. The actual blowdown volume would be appreciably smaller if segregated.

TABLE 5.
SMELTER AND REFINERY MATERIALS IDENTIFIED AS WASTES IN EPA REPORT
(continued)

Basis: 200,000 tons per year capacity

MATERIAL TYPE	OTHER REFINERY WATER	PROCESS WASTE WATER	CONTACT COOLING WATER	FURNACE BRICK	SCRAP METAL SWEEPINGS, SCREENINGS, ETC.
Description	Refinery adverse water	Identified in EPA report. No obvious match.	Identified in EPA Report. No obvious match.	Furnace brick.	Numerous
Sources(s)	Refinery; cooling system water; boiler plant blowdown; storm runoff	Not Available	Not Available	Smelter and refinery furnaces	Smelter and refinery
Fate	WWTP	Not Available	Not Available	Charged to smelter	Charged to reactor or converter, see Figure 1.
Production Rate: tons/ ton anode	2.92	Not Available	Not Available	0.007151	0.46788
Fraction Returned to Process	0	Not Available	Not Available	100%	100%
Net Production Rate: tons/ ton anode	2.92	Not Available	Not Available	0	0
Net Production Rate: @ Capacity (tons) per year	583,440	Not Available	Not Available	0	0
% Water	99%	Not Available	Not Available	0%	0%
Process Dynamics	Not Available	Not Available	Not Available	Batch, 100% at end of furnace campaigns.	Batch
Remarks	1982-1985	Not Available	Not Available	1982-1984	1982-1984

TABLE 5.
SMELTER AND REFINERY MATERIALS IDENTIFIED AS WASTES IN EPA REPORT
(continued)

Basis: 200,000 tons per year capacity

MATERIAL TYPE	CHAMBER SOLIDS AND/OR SCRUBBER SLUDGE	SPENT CATALYST FROM ACID PLANT	SLAG FROM ANODE FURNACE
Description	Boiler and cyclone dusts.	Vanadium pentoxide catalyst	Anode furnace slags
Source(s)	Air handling systems	Acid plant	Anode furnace in smelter
Fate	Charged into reactor/converter	Charged into reactor/converter	Charged into reactor/converter
Production Rate: tons/ ton anode	0.074	0.000066	0.04718
Fraction Returned to Process	100%	100%	100%
Net Production Rate: tons/ ton anode	0	0	0
Net Production Rate: @ Capacity (tons) per year	0	0	0
% Water	0	0	0
Process Dynamics	Continuous	Virtually prompt	Prompt
Remarks	Smelter Dept. estimates.	Based on Smelter Dept. estimate	Assumes that 10 tons per 225-ton charge reports as slag.

DISK: KWASTE
FILE: CONTRAST

TABLE 6. CONTRASTS BETWEEN EPA ESTIMATES AND KENNECOTT DATA

MATERIAL STREAM DESIGNATION PER EPA	MATERIAL STREAM DESIGNATION PER KENNECOTT	GROSS MATERIAL PRODUCTION RATE (TONS/TON Cu) PER EPA	GROSS MATERIAL PRODUCTION RATE (TONS/TON Cu) PER KENNECOTT	RETURN OR PROCESS FRACTION	NET MATERIAL PRODUCTION RATE (TONS/ TON Cu)	NET MATERIAL PRODUCTION RATE AS % OF EPA ESTIMATE	REMARKS
PROCESS WASTEWATER	NA	1.830000	NA	NA	NA	NA	NO CLEAR MATCH POSSIBLE
FURNACE BRICK	FURNACE BRICK	0.001700	0.007151	1.0000	0.0000	0.0%	
METAL SWEEPINGS	METAL SWEEPINGS	0.012900	0.467880	1.0000	0.0000	0.0%	
ESP BAG HOUSE ETC.	ESP BAG HOUSE ETC.	0.064000	0.036550	0.4023	0.0218	34.1%	TO BE PROCESSED IN FUTURE
CHAMBER SOLIDS	CHAMBER SOLIDS	0.076000	0.074000	1.0000	0.0000	0.0%	
SMELTING SLAG	SMELTING SLAG	3.150000	2.610000	0.1700	2.1663	68.8%	AS TAILINGS
ACID PLANT BLOWDOWN	ACID PLANT BLOWDOWN	0.882000	17.500000	0.0000	17.5000	1984.1%	TO WWTP
BLEED ELECTROLYTE	BLEED ELECTROLYTE	0.050000	0.179600	0.0000	0.1796	359.2%	TO WWTP
WWTP SLUDGE	WWTP SLUDGE	0.543000	0.386800	0.0000	0.3868	71.2%	
SPENT CATALYST	SPENT CATALYST	0.000068	0.000066	1.0000	0.0000	0.0%	
ANODE SLAGS	ANODE SLAGS	0.105000	0.047180	1.0000	0.0000	0.0%	
CONTACT COOLANT	NA	0.013000	NA	NA	NA	NA	NO CLEAR MATCH POSSIBLE
CONVERTER SLAG	CONVERTER SLAG	0.194000	0.140000	1.0000	0.0000	0.0%	
SLIMES	SLIMES	0.005300	0.005500	1.0000	0.0000	0.0%	
CATHODE WASTES	CATHODE WASTES	0.005800	0.016970	1.0000	0.0000	0.0%	
NA	DORE SLAG	NA	0.003810	1.0000	0.0000	NA	NO CLEAR MATCH POSSIBLE
NA	SMELTER ADVERSE	NA	10.500000	0.0000	10.5000	NA	NO CLEAR MATCH POSSIBLE
NA	REFINERY ADVERSE	NA	2.920000	0.0000	2.9200	NA	NO CLEAR MATCH POSSIBLE

NOTE: DURING THE PERIOD FROM 1982 TO 1984 REFINERY CONSTRAINTS PRECLUDED GREATER UTILIZATION OF FLUE DUSTS. HOWEVER, CURRENT PLANS CALL FOR 100% UTILIZATION OF THESE MATERIALS IN FUTURE OPERATIONS.

there is no basis for apportionment. Likewise, Dore slag (q.v. Table 3) and "reject anodes" were omitted in the EPA material description.

Shown also on Table 6 is the net production rate, measured as tons-per-ton copper throughput, for each of the materials. This is defined as the production rate times the quantity (1-R), where R is the return or process fraction. Materials with a positive net production rate (e.g., waste water treatment plant sludge) are the only wastes produced at this complex.

As can be seen, the only solid or liquid waste streams from the smelter/refinery complex produced over the period 1982-1984 were;

(i) Reactor slag: Although 100% of the reactor slag is treated, it is economically efficient to mill and concentrate this slag in much the same manner as ore is concentrated. Approximately 17% of the slag quantity (containing 95% of the copper input) is returned to the reactor. The balance appears as tailings and is placed in the 5,000 acre tailings pond.

(ii) Acid plant blowdown: This material is sent to the WWTP.

(iii) Smelter and refinery "adverse:"[18] These materials are sent to the WWTP.

(iv) Bleed electrolyte: This material is sent to the WWTP.

(v) WWTP sludge: This material is produced in the WWTP as a result of treating the refinery bleed electrolyte, acid plant blowdown, and smelter and refinery adverse flows.

Actual net material production rates are appreciably smaller than those estimated by EPA based on "industry average" data for most materials (see Table 5) because EPA did not account for subsequent processing in its calculations. (Note also that in listing both waste waters and WWTP sludge, EPA has counted the same material twice.)

It should be emphasized again that the data presented here describe Kennecott's operations over the period from 1982 to 1984. Post-1987 operations may differ from these historical norms. For example, future plans call for 100% reprocessing of flue dust.

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[18] This term is used at Kennecott's Utah facility to describe a water stream containing smelter sewage, runoff, and other miscellaneous streams.

Processing Rates

Another important fact of life at Kennecott's Utah facilities is that it is very difficult, if not impossible, to achieve continuous, uniform rates of processing valuable secondary materials. This is so for two reasons. First, many of these materials are produced in batches rather than continuously. For example, the anode cycle at Kennecott's refinery is 28 days, after which electrolyte is drained from the refinery cells and precious metal slimes and scrap are washed from the cell bottoms. Similarly, the maintenance cycle for the reactor furnaces at Kennecott's smelter is 180 days, after which approximately 15-20% of the furnace brick is removed. Various dusts also fit within this category, as they are collected periodically at differing rates when operating conditions permit and the need to remove them arises.

Second, the nature of Kennecott's smelting process dictates the rate at which secondary materials can be processed. The smelter charge must be kept relatively constant, and careful blending of feed streams is necessary inter alia, to maintain the copper and moisture content of the charge, the temperature within the reactors and converters, the grade of the copper matte produced in the reactor, and the chemical analysis of the anodes.

Thus, both the "supply" of and the "demand" for many of these materials is "batch-like." As a result, some of these materials are inventoried on a temporary basis. Reliable statistics on the residence time (and residence time distribution) of many of these materials are not yet available. However, EPA should be aware that the nature of the process imposes limits on Kennecott's ability to process these intermediate materials at continuous and uniform rates. Use of arbitrary rules to define "speculative accumulation" may not be an enlightened regulatory approach to this industry. Any speculative aspects relating to use of nearly all of these materials at smelters and refineries relates solely to the timing, not the fact of reuse.

APPENDIX A

SUPPLEMENTAL TABLES AND NOTES

ADDITIONAL NOTES

1. Waste Water Treatment Plant Solids
   The WWTP sludge (38% water) flow rate is 401,000 lbs/day.

$$\frac{401{,}000 \text{ lbs.}}{\text{day}} \times \frac{365 \text{ days}}{\text{year}} \times \frac{1 \text{ ton}}{2000 \text{ lbs.}} = 78{,}182.5 \quad \frac{\text{tons}}{\text{year}}$$

$$\frac{78{,}182.5 \text{ tons sludge}}{\text{year}} \times \frac{\text{year}}{189{,}182.3 \text{ tons anode}}$$

$= 0.3868$ tons sludge/ton anode

2. Bleed Electrolyte
   The bleed electrolyte flow rate is 15.4 gallons/minute.

$$\frac{15.4 \text{ gal}}{\text{min.}} \times \frac{60 \text{ min}}{\text{hour}} \times \frac{24 \text{ hours}}{\text{day}} \times \frac{365 \text{ days}}{\text{year}} \times \frac{8.4 \text{ lbs.}}{\text{gal.}} \times \frac{1 \text{ ton}}{2000 \text{ lbs.}}$$

$= 33{,}995.8$ tons/year.

$$\frac{33995.8 \text{ tons electrolyte}}{\text{year}} \times \frac{\text{year}}{189{,}182.3 \text{ tons anode}} = 0.1796 \text{ tons electrolyte/ton anode.}$$

3. Acid Plant Blowdown

   1500 gpm fluids contain acid plant blowdown plus the fresh water to the gas cooling towers, which overflow to the humidifying towers, and add to the blowdown.

$$\frac{1500 \text{ gal}}{\text{min.}} \times \frac{60 \text{ min}}{\text{hr.}} \times \frac{24 \text{ hrs}}{\text{day}} \times \frac{365 \text{ day}}{\text{year}} \times \frac{8.4 \text{ lb.}}{1 \text{ g}} \times \frac{\text{ton}}{2000 \text{ lb.}}$$

$= 3{,}311{,}280$ tons/year water containing acid plant blowdown

$$\frac{3{,}311{,}280 \text{ tons water}}{\text{year}} \times \frac{\text{year}}{189{,}182.3 \text{ tons anode}} = 17.5 \text{ tons blowdown/ton anode.}$$

4. Other Smelter Waters
   900 gpm sewage and smelter washdown.
   900 gpm = 1,986,768 tons/year, or ratio = 10.5 tons/ton anode.

5. Refinery Adverse Water
   Estimates of this stream total 250 gpm over the period from 1982 to 1984.

   250 gpm = 551,880 tons/year, or ratio = 2.92, assuming an average throughput of 189,182.3 tons anode per year.

ADDITIONAL NOTES
(continued)

6. Chamber Solids and Scrubber Sludge

There is no exact match with this stream as identified by EPA, but the streams that most closely matches this definition are "boiler dust" and "cyclone dust." Material balance calculations indicate that approximately 3,500 tpy boiler dust and 10,500 tpy cyclone dust are produced. Over the period 1982-1985, an average of 189,182.3 tons of good anode were produced, a ratio of 0.074. All of this material is continuously fed back to the smelter.

7. Anode Furnace Slags

Calculations shown 'for scrap metal, sweepings, screenings, etc., indicate that approximately 8,925 tpy is produced. Assuming an average output of 189,182.3 tpy good anodes, the ratio is 0.04718. All of this material is procesed.

8. Furnace Brick

Smelter personnel estimate that approximately 1200 tons of furnace brick from smelter furnaces were charged into the reactor. Additional furnace brick taken from the refinery includes "anode brick cobbings" and "refined brick cobbings," averaging a total of 152.9 tons per year over the period from 1982 to 1984.

$$\frac{1{,}352.9 \text{ tons brick}}{189{,}182.3 \text{ tons anodes}} = 0.007151 \text{ tons/ton anode}$$

Note that this is approximately equivalent to the value 1.35 kg/metric ton concentrate (ratio relative to copper 0.0054 for a 25% copper concentrate) value cited by Mackey et al.* for the Noranda process.

9. Spent Catalyst From Acid Plant
Smelter personnel estimate that the total quantity of spent catalyst produced is 10 to 15 tons per year. (All of this is charged to the reactor.) Choosing the midpoint of this range, 12.5 tons per year, the rate is,

$$\frac{12.5 \text{ tons catalyst}}{\text{year}} \times \frac{\text{year}}{189{,}182.3 \text{ tons anode}} = 0.000066 \text{ tons catalyst/ton anode.}$$

*Mackey, et al., "The Noranda Process - An Update," in D. B. George, and J. C. Taylor, Editors, Copper Smelting - An Update, AIME, Warrendale, Pa., 1981, p. 228.